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Egg Functionality and Quality During Long-Term Storage

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Abstract: Eggs are truly a functional food and the ability of the egg to contribute to food systems is important. The current study was undertaken to determine the changes in functional characteristics and quality factors of commercial shell eggs during 10 wk of 4°C storage. Commercially processed eggs were collected for three consecutive weeks (reps) from an in-line facility. Analyses were conducted the day after collection (0 wk) and each subsequent week. Total solids for the albumen, yolk and whole egg were determined. Functional properties were examined via preparation of angel food cakes, mayonnaise and sponge cakes. Color was also measured for both raw yolks and prepared mayonnaise. Albumen solids were fairly consistent during storage (12.2 to 12.6%). Whole egg solids remained constant. Yolk solids decreased throughout storage (48.2 to 43.2%). Angel food cake volume decreased as the egg aged. Sponge cake volumes were inconsistent throughout testing with no clearly apparent trends. Mayonnaise was tested immediately after preparation (fresh) and incubation at 50°C for 7 d. In both cases, the average force required to compress the mayonnaise decreased with egg age. Differences were detected for changes in color values (L*, a* and b*) for yolks over time, but these changes were not generally of a magnitude great enough to be seen by the human eye. Most of the measured parameters exhibited significant interactions for replicate and egg storage. These interactions show that variability exists within the testing methods and more objective methods for determining shell egg functionality need to be developed.

Key words: Shell eggs, storage, functionality, solids, quality

Introduction

Eggs have been classified as nature's original functional food (Hasler, 2000). Eggs can add many positive attributes to food products such as: emulsification, leavening, smoothness and flavor, to name a few. The determination of the functional quality of eggs can be difficult and laborious. Much of the research in the area was conducted in the 1960s and 1980s. Early studies examined the effects of processing technologies, hen age, nutrition and other management practices on the functional and quality factors of shell eggs (Marion *et al*., 1964; Ball and Gardner, 1968; Labuza *et al*., 1968; Butts and Cunningham, 1972; Fletcher *et al*., 1981; Fletcher *et al*., 1983; Izat *et al*., 1986). Many of these studies were not only conducted before the common industry practice of in-line processing facilities but also before the advent of consistent processing methodology. In more recent years, researchers have been utilizing the previously developed methods to determine the roles of new further processing interventions on egg products functionality (Harrison and Cunningham, 1986; Ball *et al*., 1987; Chang and Chen, 2000).

A comprehensive review of the functional properties of albumen and yolk has been provided by Mine (2002). Briefly, albumen has been identified as the protein-based foaming or whipping agent of choice in the food industry (Li-Chan and Nakai, 1989). Whipping test are often used to measure this quality (Baniel *et al*., 1997). For more practical information, angel food cake preparation is utilized to determine the leavening capability of albumen. In a short-term cold storage study, Sills (1974) found differences in the whipping characteristics of albumen but these differences had no effect on angel food cake volumes. Froning *et al*. (1987) also have found differences in albumen gel strength between treatments with no corresponding affect on angel food cake volume. Yolks are generally credited for the role of lipoproteins in forming and stabilizing emulsions. Most yolk functional tests involve the preparation of mayonnaise or testing oil droplet size during emulsion formation. Methods for preparing these emulsions and testing their stability have varied greatly (Cunningham, 1976; Harrison and Cunningham, 1986; Herald and Smith, 1989). Recently, more rheological-based approaches to assessment have begun to emerge (Guilmineau and Kulozik, 2007).

The current study was conducted to examine the effects of long-term cold storage on the functionality and quality of shell eggs. Eggs were acquired from an in-line facility to represent the most common industry practice (Jones and Northcutt, 2005). Furthermore, eggs were stored within the required post-processing storage temperatures for 10 wk to account for average US retail shelf time (Bell *et al*., 2001; Patterson *et al*., 2001) and additional consumer cold storage.

Table 1: Ingredients utilized in the preparation of angel food cakes

Ingredient	Amount
Homogenized albumen	180 mL
NaCl	0.9 g
Cream of tartar	2.7 g
Very fine sugar	138 g
Vanilla	2.0 mL
Granulated sugar	46 g
Cake flour	66 g

Table 2: Ingredients utilized in the preparation of sponge cakes

Ingredient	Amount
Homogenized whole egg	138 g
Granulated sugar	89.4 g
Vanilla	2.0 mL
Cake flour	51.4 g

Materials and Methods

Egg collection and sampling: Large size processed eggs were collected once a week for three consecutive weeks (replicates) from an in-line production facility. All eggs were stored in cardboard cases at 4°C for the duration of the study. Individual pools consisted of either: twelve albumen, eighteen yolks or nine whole eggs. Two pools of each type were prepared weekly from each replicate. Components were separated in a manner to ensure there was no yolk contamination of the albumen since it has been found that even slight contamination of albumen with yolk will drastically affect functionality (Cunningham and Cotterill, 1964).

Pools were equilibrated to 25°C then stomached (Model 3500, Seward Limited, London) for one minute at normal speed and stored at 4°C overnight. Samples were brought to 25°C before testing according to the recommendations of St. John and Flor (1930) who reported greater foam formation and stability with room temperature samples. Immediately before analysis, samples were stomached an additional minute at normal speed. The two pools for each replicate sample type were then combined for analysis.

Total solids determination: The total solids of whole egg and its components were determined according to the methods of Curtis *et al*. (1986). Approximately five grams of homogenized sample was placed in individual aluminum drying pans. Pans were placed in a 100°C forced air drying oven for 18-24 h and allowed to equilibrate in desiccators for at least 1 h before weighing. All measurements were conducted in triplicate. Total solids were determined from the same homogenized samples utilized for functional determinations.

Functionality determination: All functional methods were performed using three Kenwood Major Classic mixers (DeLonghi America, Inc., Saddle Brook, New Jersey) equipped with the whisk attachment. Measurements were conducted in triplicate with the exception of mayonnaise preparation which was only performed in duplicate. All mixers were allowed to run on speed six for one minute before each batch was prepared. All cakes were baked in nonstick loaf pans (7.2 cm×13.6 cm×5.5 cm; Chicago Metallic, Chicago, Illinois). Three cakes were baked from each mixer and replicate combination (weekly replicate n = 9).

Angel food cakes were prepared using a modification of the procedure outlined by Cotterill (1986). Procedures were adjusted to accommodate the mixers and oven utilized. Preliminary tests were conducted to determine appropriate whipping and baking times. The ingredients for each batch of the angel food cakes is listed in Table 1. During preparation, the albumen and NaCl/cream of tartar mixture were combined in the bowl and whipped on speed six for 45 s. The very fine sugar was added in three increasingly larger portions by mixing at speed five for 4 s after each addition. The vanilla was then incorporated at speed five for 4 s. The flour and granulated sugar for each batch was double sifted then folded in the batter in three equal portions using a hand whisk and fewer than 20 strokes for each addition. Seventy-five grams of batter was weighed into each baking pan. The cakes were baked in a 199°C oven for 13.5 min.

Sponge cakes were prepared by modifying the methods of Norris and Cotterill (1986). The ingredients for each batch of sponge cakes can be found in Table 2. The homogenized egg was placed in the mixing bowl with the granulated sugar and combined on speed one for 15 s. The mixer speed was then increased to six and whipped for 4 min. The vanilla was added and incorporated on speed five for 4 s. The flour was folded into the batter in four equal portions with the aid of a hand whisk using fewer than 20 strokes for each addition. Seventy-five grams of batter was weighed into each pan and baked at 177°C for 14 min.

All baked cakes were immediately inverted onto cooling racks for at least 2 h before determining final cake volume. Each cake was dusted with flour before rapeseed displacement measurements were conducted to prevent seeds from sticking to the cake surface.

Mayonnaise was prepared according to a modification of the method reported by Guerrero and Ball (1994). Modifications were necessary to accommodate available mixers. The ingredients utilized for each batch of mayonnaise are listed in Table 3. An initial mixture of 120 g soybean oil, white vinegar and NaCl was made in each mixer bowl. The yolk was added and mixed on speed six for 10 s. Kilgore (1935) found the physical conditions of the starting mixture were important in mayonnaise preparation. The paste formed must have enough water to start the emulsifying process. The remaining soybean oil was added at a constant rate over a 2.5 min period with the mixer running at speed six. The

Table 3: Ingredients utilized in the preparation of mayonnaise

Ingredient	Amount
Homogenized yolk	79.5 g
NaCl	10.5 g
White vinegar	50.0 g
Soybean oil	120.0 g
Soybean oil	240.0 g

mayonnaise was then whipped an additional 7.5 min at speed six. Sixty grams of mayonnaise was placed in each of six 100 mL glass beakers for each mixer and replicate combination. Care was taken to ensure no air bubbles remained trapped in the mayonnaise after being placed in the beaker. Three beakers were sampled immediately (fresh) and three were sealed with parafilm and a no. 10 rubber laboratory stopper and stored at 50°C for 7 d before analysis (stored).

Mayonnaise force measurements were made utilizing a TA-XTplus Texture Analyzer (Texture Technologies, Scarsdale, New York) with a 5 kg load cell. A 25 mm cylindrical probe at a test speed of 1 mm/s was submerged 10 mm into each sample. Peak force (in grams) was recorded. Stored samples were allowed to equilibrate to room temperature before force determinations were made since Harrison and Cunningham (1985) have previously reported that temperature can affect the consistency of measurements when testing mayonnaise.

Yolk and fresh mayonnaise color measurements were made using a Minolta CR300 Colorimeter (Minolta Co., Ltd., Osaka, Japan). Prior to measuring color, the colorimeter was standardized with a white ceramic reference tile (reference number 13533123). The CIE illuminance scale was used to determine L*, a* and b* values. Six readings were taken from each pooled yolk sample and batch of mayonnaise before distribution to beakers. All measurements were conducted at room temperature.

Statistical analysis: All data were analyzed via the general linear model procedure of SAS (1999). Means were separated by the least squares method.

Results

The effects of long-term storage on albumen and whole egg total solids and functionality are presented in Fig. 1-3. For all parameters measured, significant ($p<0.001$) storage and replicate interactions were detected. Albumen total solids were fairly consistent throughout storage (low: 12.2%; high: 12.59%; Fig. 1). The average volume of angel food cakes produced ranged from 390.44 mL at 0 wk to 362.74 mL at 8 wk (Fig. 2), with a general trend of decreasing cake volume during storage ($p<0.001$). The visual trend of increasing albumen solids and corresponding decreasing angel food cake volume were also found in a study examining the effects of

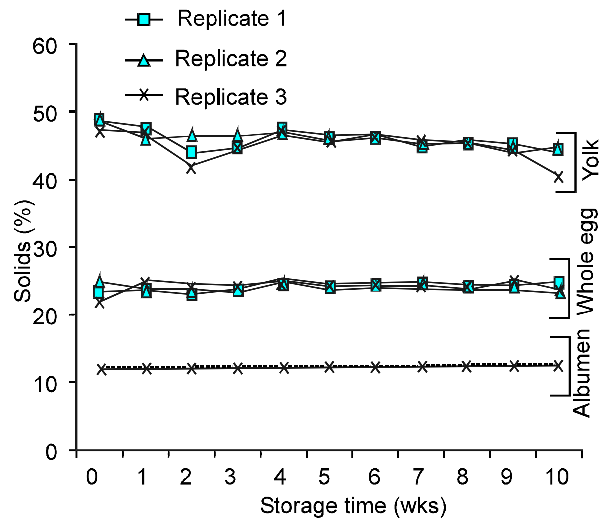

Fig. 1: Effect of storage and replicate on whole egg ($p<0.001$), albumen ($p<0.001$) and yolk total solids ($p<0.05$)

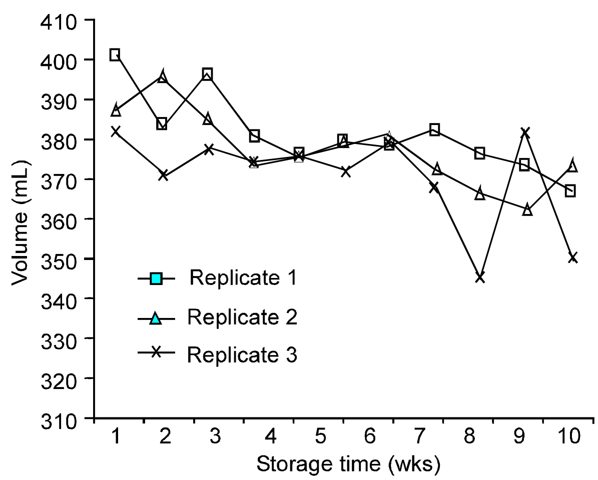

Fig. 2: Effect of storage and replicate on angel food cake volume ($p<0.001$)

irradiation on albumen functionality (Ball and Gardner, 1968). Whole egg total solids remained steady throughout the course of the storage period (Fig. 1). Sponge cake volumes increased slightly above initial levels as the eggs were stored ($p<0.001$; Fig. 3). Ball *et al*. (1987) also have reported difficulty finding differences amongst samples when comparing sponge cake volume.

The yolk total solids storage and replicate interaction is depicted in Fig. 1 ($p<0.05$). Yolk total solids decreased during storage from a maximum of 48.25% at 0 wk to 43.17% at 10 wk. The greatest force measurements for both fresh ($p<0.001$) and stored ($p<0.001$) mayonnaise were found at 0 wk of storage (422 and 400 g; Fig. 4 and 5, respectively). The firmness of mayonnaise produced

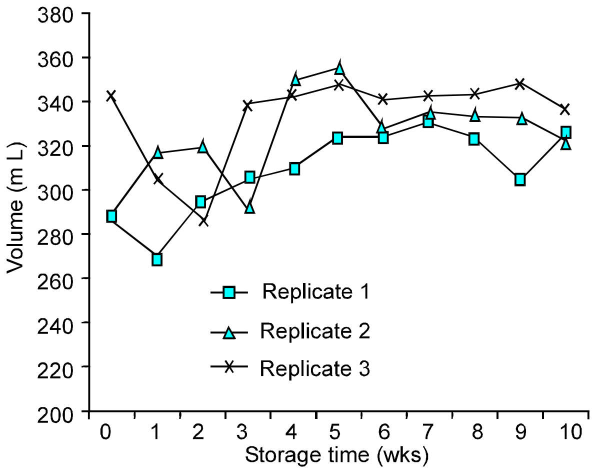

Fig. 3: Effect of storage and replicate on sponge cake volume (p<0.001)

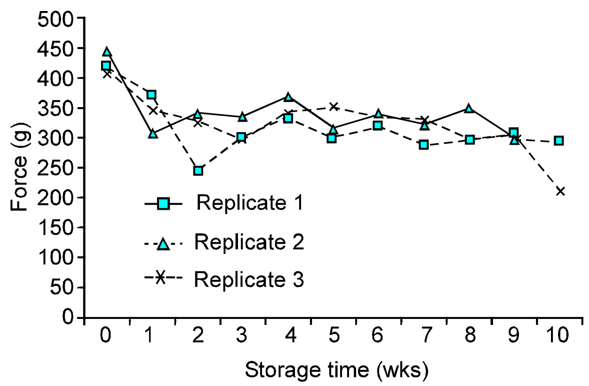

Fig. 4: Effect of storage and replicate on fresh mayonnaise strength (p<0.001)

during the remainder of the study continually declined. For both fresh and stored mayonnaise samples, the difference between 0 wk and 1 wk force measurements was about 70 g. The difference between 1 wk and 10 wk force measurements for both fresh and stored samples was approximately 80 g. During this same time, yolk solids also decreased. Cunningham (1976) has also reported emulsification capacity and viscosity to be greater when yolk samples had a higher percentage of solids.

Significant (p<0.0001) storage and replicate interactions were found for L*, a* and b* values in the pooled yolk samples. During the extended storage, the average L* values ranged from 59.85 to 63.12 (Fig. 6). For a* values, average reading were-1.11 to 0.95 (Fig. 7). Furthermore, average b* values were recorded between 47.53 and 51.05 (Fig. 8). All of these differences were not large enough to be of practical significance. While statistically these values may be significant, their impact on the consumer would be minimal.

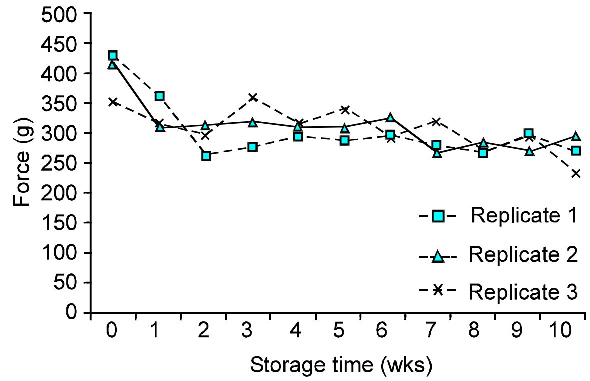

Fig. 5: Effect of storage and replicate on stored mayonnaise strength (p<0.001)

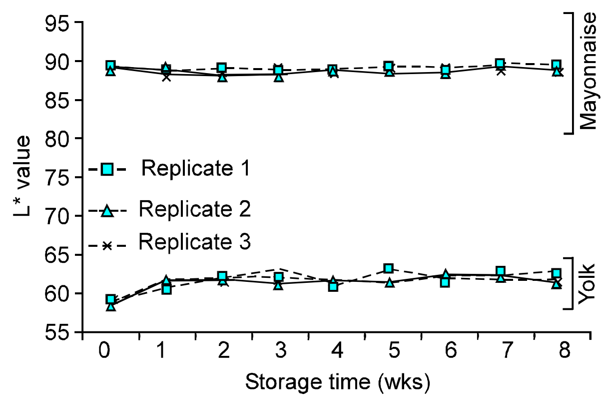

Fig. 6: Effect of storage and replicate on L* values for yolk (p<0.0001) and mayonnaise (p<0.0001)

When fresh mayonnaise color was analyzed, significant storage and replicate interactions were found for L* and b* values (p<0.001). Once again, these differences were minimal. Average L* values ranged from 88.68 to 89.33 (Fig. 6). The average b* values varied from 27.01 to 29.19 (Fig. 8). As stated previously, these differences would be difficult for the consumers to detect.

Discussion

Over the 10 wk of storage, yolk solids decreased while albumen experienced a slight increase and whole egg solids remained consistent. The percentage of total solids detected in this study were in accordance with those reported by Stadelman and Cotterill (1995). They reported egg solids to be: albumen, ~ 12%; yolk, 44-48% (from commercial egg separators); and whole egg, 23-25%.

On average, angel food cake volumes decreased as the eggs aged which corresponded with a slight increase in albumen total solids. Average sponge cake volumes remained relatively consistent throughout storage as did whole egg solids. Fresh and stored mayonnaise firmness was similar throughout egg storage. The

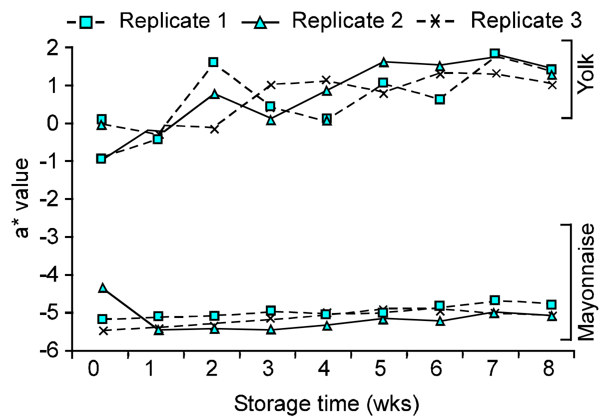

Fig. 7: Effect of storage and replicate on a* values for yolk (p<0.0001) and mayonnaise

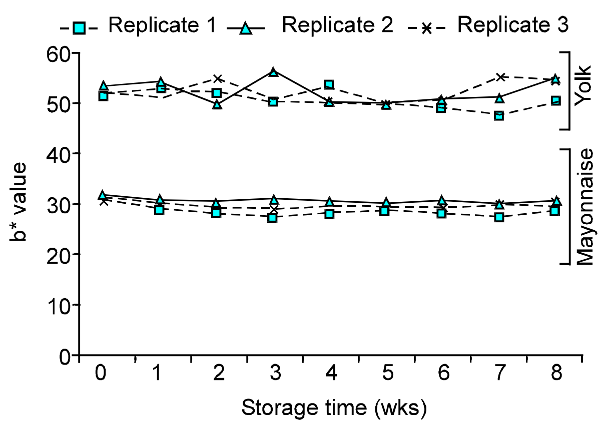

Fig. 8: Effect of storage and replicate on b* values for yolk (p<0.0001) and mayonnaise (p<0.0001)

greatest drop in the functional characteristic of egg yolk was observed between 0 and 1 wk of storage as determined by mayonnaise preparation. The differences in L*, a* and b* color measurements were minor. There were approximately 3-5 point differences between high and low color values for each L*, a* and b* values during the study. In our laboratory, when color measurements were made on a yolk color fan, the changes for L*, a* and b* between two consecutive fans was 1-4 points. While these differences are perceived by the human eye, the gradual change in color readings during this long-term storage study would be limited in human perception.

The results between the replicates were variable leading to significant interactions between storage and replicate. Egg to egg variability can be considerable and is affected by hen health, nutrition, management practices and other factors. Lechevalier *et al.* (2005) determined that raw materials accounted for 70% of the variability in functional quality when comparing egg treatments. The subjective nature of testing procedures can also contribute to the inconsistent trends in the data. Stadelman and Cotterill (1995) have stated that whipping test results are difficult to compare from one laboratory to another due to differences in equipment, method and data expression. In particular, during cake preparation, the flour mixtures must be folded in by hand, adding even more variability to the process. The oil is gradually added during mayonnaise preparation, thus adding a human variability aspect. Together with the results of this study, the need for more objective measurements for the assessment of egg functionality can be seen. Guilmineau and Kulozik (2007) have reported on rheological methods for assessing mayonnaise viscosity and pseudoplasticity. More methods such as these need to be developed to allow for better comparison of functional results. When product quality is gauged by product performance, definitive testing methods are needed for accurate assessment.

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